The Pigmentary Dispersion Disorder in USAF Aviators

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PETERS DR, GREEN RP JR. *The pigmentary dispersion disorder in USAF aviators.* Aviat. Space Environ. Med. 1992; 63:1049–53.

The pigmentary dispersion syndrome (PDS) can have serious ocular consequences. Visual changes due to glaucoma and the treatment required can threaten the high level of visual function necessary in military aviation. We reviewed the records of 50 aviators with PDS who were evaluated at the Aeromedical Consultation Service (formerly the USAF School of Aerospace Medicine) over the past 10 years. At last evaluation, 48 were still qualified to fly. Only two aviators were permanently removed from flying duties due to glaucoma. Initial intraocular pressures, cup-to-disc ratios, and refractions were not statistically correlated with progression to glaucoma, but sample sizes were small. At final evaluation, 20 of the 34 aviators with follow-up had glaucoma and required medication. Thirteen eyes underwent laser trabeculoplasty. With appropriate management, the majority of aviators with PDS were able to safely continue their flying careers.

DISPERSION OF PIGMENT in the anterior segment of the eye (pigmentary dispersion syndrome or PDS) is a disorder most often afflicting young, white, male adults (4,7,10). A significant number of these patients go on to develop pigmentary glaucoma (PG) (13).

The Ophthalmology Branch of the Armstrong Laboratory (formerly the United States Air Force School of Aerospace Medicine) is particularly concerned about the impact of this ocular disorder on aviators, because young white males currently comprise the largest segment of Air Force flyers. The financial effect to the American public alone is enormous when a pilot is removed from flying duties. It costs up to $8 million and takes 4 years to train a fully combat-ready pilot.

Previous studies have not explored the effect of the pigmentary dispersion disorder on the careers of young professionals who require excellent vision for their continued employment. To answer this question and determine risk factors, we retrospectively evaluated the visual and functional status of aviators with PDS referred to us over a 10-year period.

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This manuscript was received for review in March 1992. It was revised and accepted for publication in June 1992.

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MATERIALS AND METHODS

Patient Selection

This Ophthalmology Branch serves a consultant function to the USAF Surgeon General for aviators who have been disqualified from flying due to an ocular condition or disease. Accordingly, we recommend aircrew visual standards for selection and retention. Air Force pilots, navigators, and other aircrew members, are required to maintain stringent visual standards. Their visual acuity and various visual functions are tested annually by local flight surgeons. Aviators are generally referred from their local flight surgeon to the Ophthalmology Branch once diagnosis, treatment, and resolution or stabilization of the ocular problems have occurred. Individuals who are pigmentary glaucoma suspects or who have pigmentary glaucoma are referred to the Branch. Those with only pigment dispersion are usually not referred.

There were 50 aviators with the pigment dispersion syndrome who were seen by the Ophthalmology Branch between January 1977 and April 1988. Some of these aviators had been evaluated one or more times at this institution prior to 1977.

Patient Evaluation

At each evaluation, a detailed history was obtained concerning the following points: age; sex; race; ocular trauma; diagnoses and dates; involved eye or eyes; number and types of medications; argon laser trabeculoplasty or other ocular surgery; ocular symptoms or problems; aeromedical dispositions; and family history. The aviators received a full ophthalmologic examination and special testing that focused on, but was not limited to, the following: visual acuity; refraction; pupillary reaction; diurnal applanation intraocular pressure (IOP) range (at 0800, 1000, 1200, 1400, 1600 hours); slit lamp and gonioscopic findings (Krukenberg spindles, iris transillumination defects, trabecular pigment); stereo-

scopic optic nerve evaluation; and Armaly-Drance paradigm, kinetic Goldmann visual fields, or automated Humphrey static visual fields.

Diagnostic Criteria

The diagnostic criteria of Migliazzo et al. (8) were used to identify the three diagnostic categories. Individuals with the pigmentary dispersion syndrome (PDS) had 2+ or more trabecular pigment coupled with iris transillumination defects and endothelial pigment dusting (Krukenberg spindles). Pigmentary glaucoma suspects (PGS) had the finding of PDS and, in addition, IOP readings equal to or greater than 22 mm Hg. They also had normal visual fields and optic nerves. Aviators with pigmentary glaucoma (PG) demonstrated the iris and pigment findings of PDS, had elevated IOP readings equal to or greater than 22 mm Hg, and, further, had one or more of the following: characteristic glaucomatous visual field loss; glaucomatous disc cupping greater than 0.5 and/or cup asymmetry >0.2 that correlated with either asymmetric intraocular pressures or visual field changes.

Aeromedical Disposition Criteria

Individuals with only PDS do not require a waiver either to enter flying training or to continue flying. Individuals who are PGS require waivers, on a case-by-case basis, to enter flying training. Already-trained flyers who are PGS usually receive waivers to continue flying, but require regular ophthalmologic follow-up. Individuals with PG do not receive waivers to enter flying training but may receive waivers to continue flying, provided that the following conditions are met: the glaucoma is controlled with aeromedically acceptable topical medications (epinephrine and/or beta blocker) and/or laser trabeculoplasty; they suffer no visual or systemic side-effects from that treatment; they have no significant visual field defects; they receive close ophthalmologic follow-up.

Individuals requiring pilocarpine and carbonic anhydrase inhibitors are not given waivers due to the visual (miosis, induced myopia, fluctuating refraction) and systemic (dehydration, sensory changes, fatigue, etc.) complications of these medications.

Statistical Analysis

Data in this retrospective study were summarized using Statistical Analysis System Institute software. Statistical significance was considered to be $p < 0.05$. Multivariate regression analysis was used to determine whether initial IOP values, cup/disc ratios, or the spherical equivalent refractions were predictive for progression to PG. Correlation of the initial distribution of refractions and progression to PG was also analyzed using the logistic regression equation. The generalized Wilcoxon and Logrank tests were used to determine whether the incidence of progression to PG in the PGS group was statistically different from the group with only PDS.

RESULTS

Patients

Of the 50 aviators, 26 were pilots, 16 were navigators, and 8 occupied other aircrew positions. All flyers were male Caucasians. The mean age at diagnosis of the pigmentary dispersion disorder was 38 years, with a range of 21 to 57 years. Of the 50, 39 (78%) were myopic, 3 (6%) emmetropic, and 8 (16%) were hyperopic. The prevalence of the pigmentary dispersion disorder in the aviators, when initially evaluated at our center, was 1% (50/5012 seen). The denominator of 5012 includes all aviators evaluated at USAFSAM during this period. Of the 50 aviators, 24 were first diagnosed with PDS incidentally, during evaluation at USAFSAM for other medical problems.

Follow-up

Of the 50 aviators, 34 (68%) had follow-up at the Ophthalmology Branch. The remaining portion of the Results section, with the exception of aeromedical status, deals only with these 34. Their mean age, at initial evaluation, was 37 years. Limited follow-up data were available on the other 16 of the 50 aviators, either because they were permanently removed from flying duties ("grounded") due to glaucoma (2), or because they had only PDS and were, thereafter, followed locally (14). Their follow-up data were obtained from USAF records and a telephone survey. Individuals that were PGS or had PG were followed by their local ophthalmologist every 6–12 months, as indicated. In addition, they were re-evaluated by us every 1 to 2 years.

The mean follow-up period was 5.3 years, ranging from 7 months to 18.3 years. Less than 5 years of follow-up was available on 22 aviators, 5–10 years on 9 aviators, and more than 10 years on 3 aviators.

Diagnoses

The initial and final diagnoses, for the 34 aviators with follow-up, are listed in Fig. 1. Six aviators (18%) had PDS at the initial evaluation. Five of these had no change in diagnosis during their follow-up periods. One did develop elevated IOPs by the final evaluation and, therefore, met the criteria for the diagnosis of PGS. None progressed to PG. Fifteen aviators (44%) were diagnosed as being PGS at their initial evaluations. Of these, seven progressed to PG by their final evaluation. The difference in progression to PG between the PDS and the PGS groups was not statistically significant. Thirteen aviators (38%) had PG at initial evaluation and had no change in diagnosis during their follow-up. Thus,

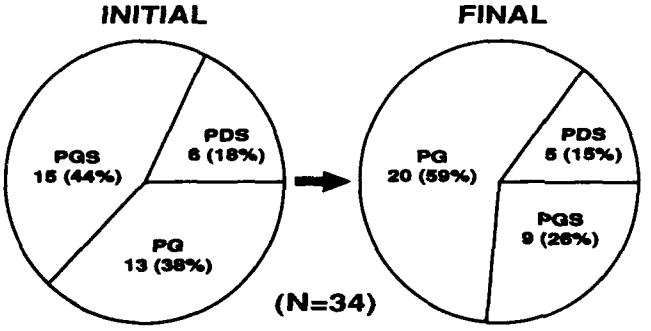

Fig. 1. Initial and final diagnoses of the follow-up group of 34 aviators. Most of the change is represented by those glaucoma suspects who developed pigmentary glaucoma.

Dec 1992 Journal Article 1977 to 1988

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AL-TR-1991-0074

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pigmentary dispersion disorder, hypertension, glaucoma, USAF, aviators 5

Unclassified Unclassified Unclassified None

20 aviators, or 59% of those with follow-up, had PG by final evaluation.

Visual Acuity and Gonioscopy

All 34 patients with follow-up had best-corrected visual acuities of 20/20 or better O.U. at each evaluation, and none lost visual acuity during follow-up. All 34 patients had open angles.

Age at Progression

The ages (in years) at which the seven aviators progressed from PGS to PG varied. One was 22; two were between 30–39; and four were over 40. Too few progressors were available to determine whether age was correlated with risk of progression.

Intraocular Pressure

On initial evaluation of the 34 aviators, those with PDS had a mean daytime diurnal IOP of 15 mm Hg (range 13–18), those who were PGS had a mean of 22 mm Hg (range 15–36), and those with PG had a mean IOP of 23 mm Hg (range 14–31).

Initial daytime diurnal IOP statistical means for those aviators with the diagnosis of PDS or PGS were evaluated for correlation with progression (14 eyes) versus nonprogression (28 eyes). This correlation is charted in Fig. 2. There were 22 eyes (53%) that had initial mean IOPs which were ≤22 mm Hg, 4 of which progressed to PG. There were 17 eyes (40%) that had mean IOPs between 23–30 mm Hg, 8 of which progressed. Of three eyes (7%) with initial mean IOPs > 30 mm Hg, two developed abnormal discs or visual field deficits. The overall mean initial IOPs for all nonprogressor eyes was 18 mm Hg, as compared to 24 mm Hg for the progressors, a difference that was not statistically significant.

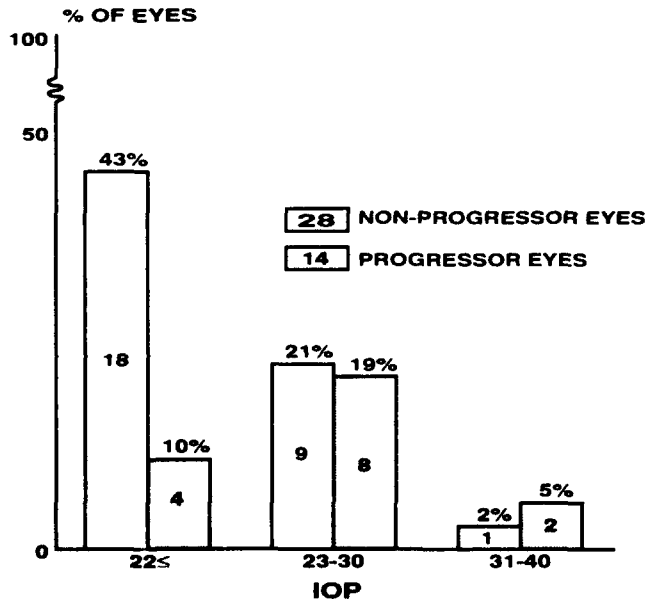

Fig. 2. Initial intraocular pressure distribution for the follow-up group of 34 aviators. Non-progressor eyes tended to have lower initial pressures, but this distribution was not statistically significant.

Refraction

Overall, 28 (82%) of the 34 aviators were myopic [more than 0.25 D of minus], 3 (9%) were hyperopic [more than 0.25 D of plus], and 3 (9%) were emmetropic.

The eyes with PDS and PGS were grouped by refraction and analyzed with regard to progression. Of the 12 eyes with PDS, 8 were myopic and 4 were emmetropic. Of the 30 eyes in the PGS group, 24 were myopic, 2 were emmetropic, and 4 were hyperopic. Of the 32 myopic eyes, 10 (31%) progressed to glaucoma. Of the 4 hyperopic eyes, 2 (50%) progressed to glaucoma. Two of the six (33%) emmetropic eyes also progressed to glaucoma. Overall, the mean initial refraction of the nonprogressors was relatively less myopic, at −0.88 D, than that of the progressors, at −1.16 D. However, this difference in refractive error is not statistically significant for predicting either progression or nonprogression.

Cup to Disc Ratios

Initial and final mean, horizontal cup-to-disc (C/D) ratios for each diagnostic group (PDS, PGS, PG), as annotated by the examining ophthalmologist, were analyzed for the 34 aviators. The methods for estimation of the C/D ratio were not defined. The mean initial and final C/Ds for aviators in the PDS group were 0.23 and 0.25, respectively, a difference of 0.02. Mean initial and final C/Ds for the PGS group were 0.30 and 0.34, a difference of 0.04. The means for those aviators diagnosed with PG were 0.48 and 0.55 at initial and final evaluations, a difference of 0.07. These mean differences were compared using a F-test one-way analysis of variance. Mean ratios for each group were compared to the other two groups and to the combined mean of all three groups. No statistically significant difference was found, although the trend toward larger differences was interesting.

Visual Fields Abnormalities

All visual fields from each evaluation were reviewed and characterized by one of the authors (RPG) who was blinded to intraocular pressure, cup/disc ratio, name, etc. At the time of the initial evaluation, 9 of the 68 eyes seen in follow-up (5 flyers) had a visual field abnormality compatible with the diagnosis of glaucoma. All aviators with such an abnormality were diagnosed as having PG and were seen at least once in follow-up. At final evaluation, 14 eyes had visual field defects (9 aviators). The flyers and their visual field defects, at both the initial and final evaluations, are listed in Table I. The original visual field defects resolved or were not reproducible in two eyes, while new field abnormalities were discovered in seven eyes with previously normal visual fields. Some fields have more than one type of defect, a finding which was much more common at the final evaluation. Early visual fields were generally kinetic Goldmann tests, while final fields were usually automated Humphrey static threshold tests.

Medical Treatment

Medically treated eyes at initial and final evaluations, along with the number and percent receiving each type of medication, are listed in Table II. All medically

TABLE I. VISUAL FIELD ABNORMALITIES LISTED BY EYE INVOLVED, DEFECT TYPES, AND WHETHER DEFECTS WERE FOUND ON INITIAL OR FINAL EVALUATION.

Patient	Eye	Initial	Final
1.	OD	NL	*PC, NS
	OS	NL	*NL
2.	OD	NL	NL
	OS	NL	PC (small)
3.	OD	NL	*NS, PC, BS
	OS	NL	*PC, BS
4.	OD	NL	*PC, NS
	OS	NL	*PC, NS
5.	OD	NS	NL
	OS	BS	NL
6.	OD	BS, PC	*NS
	OS	NS	*NS, A, PC
7.	OD	BS, PC	*A
	OS	BS, PC	*A, NS
8.	OD	SD, NS	*NS, Q, PC
	OS	SD,	*PC, NS
9.	OD	NL	*NS (mild)
	OS	PC	*B, NS
Total abnormal fields		9	14

KEY: NL = Normal; NS = Nasal step; BS = Enlarged Blind Spot; PC = Paracentral Scotoma; SD = Superior Depression; A = Arcuate defect; B = Bjerrum defect; Q = Quadrant defect; * = Humphrey visual field.

treated eyes had the diagnosis of PG. At initial evaluation, 26 of the 68 eyes (15 flyers) seen in follow-up (38%) required medical treatment. Three of these eyes required treatment with more than one medicine to control the IOP. There were 14 eyes initially treated with epinephrine, 2 eyes with pilocarpine, 2 eyes with dipivalyl epinephrine, and 11 eyes with timolol. At final evaluation, 40 eyes (59%) in 21 flyers required medication, and 14 of these eyes needed more than one medication. Only 14 eyes were being treated with epinephrine compounds; many others had to stop these compounds due to hypersensitivity reactions. Two eyes required pilocarpine. However, 38 eyes were being treated with timolol.

Surgery

Laser trabeculoplasty was employed to control IOP in 13 of the 40 eyes with PG (7 flyers). Seven eyes received 180° of treatment. Four eyes received 360° of treatment, and two eyes were initially treated over 360° and later retreated over 180°. All eyes, except two (one aviator), were treated during follow-up evaluations at the Ophthalmology Branch. Eleven eyes (85%) had an initial IOP decrease, but later elevation to pretreatment levels requiring either restarting prior medication regimens or adding additional medications in order to achieve adequate control. Two eyes had an initial decrease in IOP which allowed dipivalyl epinephrine to be discontinued; these eyes were successfully controlled long-term with timolol only. All 13 eyes required treatment with at least one medication at the last evaluation, and 8 of these eyes (62%) required more than one medication.

No eyes underwent surgical trabeculectomy or full thickness procedures.

TABLE II. MEDICATIONS REQUIRED TO TREAT PIGMENTARY GLAUCOMA AT INITIAL AND FINAL EVALUATIONS.

	Initial (26 eyes)	Final (40 eyes)
L-Epinephrine	14 (54%)	6 (15%)
Dipivalyl Epinephrine	2 (8%)	8 (20%)
Pilocarpine	2 (8%)	2 (5%)
Timolol	11 (42%)	38 (95%)

Aeromedical Status

The pigmentary dispersion syndrome rarely forced the removal of the flyer from flying duties. Of the original 50 aviators, 14 received initial waivers for the diagnosis of PDS and did not require, nor were they ever referred back for, our follow-up. At the time of their separation, retirement, or last known active duty status, 8 of these 14 aviators were in flying jobs and 4 were in nonflying jobs. Flying status information could not be obtained on 2 aviators.

An additional 34 aviators were initially waived for the diagnoses of PDS, PGS, or PG, and received follow-up examination at the Ophthalmology Branch.

Therefore, 48 or 96% of all aviators were waived for flying duties. One aviator was initially "grounded" for pigmentary glaucoma. One aviator was later "grounded" for PG, because he demonstrated progressive and significant visual field changes. Thus, only two aviators (4%) were "grounded," either at the initial evaluation or during follow-up. No aircraft accidents or incidents, due to vision, were reported by any of the flyers, nor are any recorded for these flyers at the USAF Flight Safety Center.

DISCUSSION

This study reports on the long-term follow-up of a group of young and middle-aged male USAF aviators with the diagnoses of PDS, PGS, and PG. Significantly, only two aviators from the original group of 50 were removed from flying duties because of eye disease. The vast majority (96%) continued to remain waived for flying duties with appropriate ophthalmologic monitoring. We believe the data reported in this study support a good long-term, functional visual prognosis for aviators with this ocular disease process.

In general, most authors have reported a relatively good long-term visual prognosis in patients with either PDS, PGS, or PG. In 1986, Migliazzo (8) reported that, despite a 35% rate of eventual progression from PDS or PGS to PG, irreversible loss of acuity was rare with treatment. The syndrome may actually improve with age, either because the ever-enlarging lens gradually brings about less zonular-iris touch or because all susceptible neuroepithelial pigment has been released (2,11). Our overall progression rate to PG in the 48 aviators with PDS or PGS on initial examination was 15%. No aviator in our group demonstrated a loss of acuity; with few exceptions, disease progression was mild.

Most reports state that the pigmentary dispersion disorder is more common in males (8,10,13). All of our patients were males, due to past USAF qualification policies for flying training.

Reports have identified the usual mean age of males, upon diagnosis of the pigmentary dispersion disorder, to be 40–46 years (8,12) and, upon diagnosis of pigmentary glaucoma, to be 34 to 46 years (1,8,12,16). We found that the overall mean age at diagnosis of the pigmentary dispersion disorder was 38 years. The mean age upon diagnosis of pigmentary glaucoma, in our study, was 37 years.

Most studies have found that myopes are overly represented in the patient population with the pigmentary dispersion disorder, varying from "almost every case" (5) to 35% (4). Among pigmentary glaucoma patients, most studies have similar findings (77%, Sugar; 78%, Lichter and Shaeffer) (6,13). We found that, of those initially diagnosed with the pigmentary dispersion disorder, 78% were myopic, 6% were emmetropic, and 16% were hyperopic. Further, among pigmentary glaucoma patients, 90% were myopic, and 10% were hyperopic. Based on a 1989 survey of 6,455 aeromedical records at 12 bases, 31% of aircrew members wore spectacles for myopia and 5% wore spectacles for hyperopia. The rest wore no spectacles (9).

The fact that the method of testing visual fields changed over the years may introduce a testing bias. Most aviators did not receive Goldmann visual fields, in addition to the Humphrey visual fields, at the final evaluation to exclude this possibility. Since the Humphrey is a sensitive threshold testing device, it might tend to find more defects than the Goldmann. Further, it is not clear why the visual field defects resolved in two eyes. This could happen for many reasons, from simply test-giving or test-taking differences to actual resolution of defects due to treatment. We are aware that the fate of the 14 aviators with PDS who were not seen by us for follow-up cannot be assumed with certainty. However, they were reevaluated by other examiners, and the aviators relayed the findings to us. We are aware that the intra- and inter-examiner variability in estimating cup-to-disc ratios can be wide. It is impossible to exactly determine how this might bias our report, as there were so many examiners.

Variable follow-up occurred because aviators with minimal risk for disease progression (i.e., PDS) generally did not return to us for reevaluation. In other cases, aviators left the military while still young. In the military setting, when trying to decide whether or not to invest several million dollars in flying training expenses on an individual, an effective predictor of disease progression would be an extremely useful tool. Unfortunately, our search for such a predictor in this group was disappointing, as it has been in nonflying individuals. Progressors had higher initial IOPs, larger initial cup/disc ratios, and greater degrees of myopia, as compared to nonprogressors. However, none of these differences was statistically significant at the 0.05 level, although the small sample sizes mean that the tests were of low power. As more data are collected, we are hopeful that a statistically significant predictor may yet emerge.

The Armstrong Laboratory Ophthalmology Branch will continue to offer already-trained aviators with glaucoma the previously described graduated treatment regimen. If this fails, then treatment with a miotic would require removal from flying duties.

Our current recommendation policies will not change. Individuals having only pigmentary dispersion (not PGS or PG) should be considered qualified to enter flying training. If the trend continues, however, in which nearly 50% of pigmentary glaucoma suspects develop pigmentary glaucoma, waivers for these candidates to enter flying training may be discontinued. Our finding on this matter is supported in a recent paper (3) in which a 50% progression rate to PG among all pigment dispersion patients was found. Furthermore, this paper reported that 50% of the patients with PG required laser trabeculoplasty, compared with our finding of 32%. Individuals with pigmentary glaucoma should not be entered into flying training.

This study suggests that the long-term aeromedical disposition of experienced flyers with the pigmentary dispersion disorder, across its continuum, is generally good. Only 4% were ever permanently disqualified from flying duties because of their eye disease. Thus, for young professionals with the pigmentary dispersion syndrome in careers that demand excellent vision, there is an excellent outlook.

Further studies, performed in a prospective manner and involving larger numbers of patients with longer follow-up, are required to reach definitive conclusions regarding risk factors.

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